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TITLE: **Liquid crystal element**

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1. TITLE OF INVENTION

Liquid crystal element

2. PATENT CLAIMS

[Claim 1]

A liquid crystal element which characteristically possesses the first pair of comb-tooth electrodes and the second pair of comb-tooth electrodes, both of which are constructed with two comb-tooth electrodes, each having a section of multiple comb-teeth which is aligned alternatively from each other, by being positioned through the liquid crystal layer, wherein the said first pair of the comb-tooth electrodes and the second pair of the comb-tooth electrodes are positioned so that their length **[Note from the Translator-2]** directions intersect each other.

[Claim 2]

The liquid crystal element described in Claim 1 wherein the length directions of the said comb-tooth sections intersect each other by forming a 45 degree angle.

3. DETAILED EXPLANATION OF INVENTION

[Industrial Application Fields]

The present invention relates to a liquid crystal element driven at high speed, further more in details, to the liquid crystal element which can be utilized in a shutter array for the printer photo-writing.

[Conventional Techniques]

The liquid crystal element which can be utilized in a shutter array for the high speed printer photo-writing is strongly urged. The conventionally known liquid crystal element of this type is the liquid crystal element driven by the forced electric fields in two directions. Figure 6 presents the schematic constitution of the said conventional type liquid crystal element by disassembling.

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In this figure, the said conventional liquid crystal element indicated by code 1 is schematically constructed with: a liquid crystal layer 2 comprising a nematic liquid crystal; a pair of comb-tooth electrodes 3 and a counter electrode 4 which hold the said liquid crystal layer 2; substrates 5 and 5 which are placed at the outside of these comb-tooth electrodes 3 and counter electrode 4 and support these comb-tooth electrodes 3 and counter electrode 4; and polarizers 6 and 7 which are perpendicular to each other and placed at the outside of these substrates 5 and 5. In this liquid crystal element, the said liquid crystal layer 2 comprises a nematic liquid crystal of which liquid crystal molecules are homogeneously aligned, i.e., aligned parallel to both of the surfaces of the substrate 5 and 5 as well as to the same direction, as shown in the cross-sectional constitution diagram in Figure 7.

Further, the said pair of the comb-tooth electrodes are constituted with two comb-tooth electrodes 10 and 10 having multiple comb-tooth sections 9, 9..... by facing to each other on the substrate 5. In concrete, the comb-tooth sections 9, 9..... of the said two comb-tooth electrodes 10 and 10 are arranged by facing each other alternatively to form a stripe-like structure. These comb-tooth sections 9, 9..... are formed in a line shape with the same interval from each other. The materials for the said pair of the comb-tooth electrodes 3 are, for example, metallic materials such as chromium and copper, and transparent conductive materials such as indium-tin-oxide (ITO). Further, the said counter electrode 4 is a transparent plane electrode and is placed by facing to the pair of the comb-tooth electrodes through the liquid crystal layer 2. Further, the said polarizers 6 and 7 which are perpendicular to each other are placed so that their polarizing axes form 45 degree angles from the length direction of the comb-tooth sections 9, 9.... of the comb-tooth electrodes 10 and 10.

In the said constitution, when an alternating current is applied between the said pair of the comb-tooth electrodes 10 and 10 so that one comb-tooth electrode 10 is at the reverse phase of the other comb-tooth electrode 10, as shown in Figure 8, an electric field parallel to the substrates 5 and 5 is generated between the adjacent comb-tooth sections 9, 9.... .

As a result, the liquid crystal molecules 8 align to the electric field direction, therefore, the molecular alignment is in the direction to cross the comb-tooth sections 9, 9.... (the direction perpendicular to the length direction of the comb-tooth sections 9, 9....) and the direction parallel to the substrates 5 and 5. In such the molecular alignment condition, the incident light to the polarizer 6 enters the liquid crystal layer 2 as the linear polarized light P_a. As shown in Figure 6, the vibrational plane direction of the linear polarized light P_a (direction of arrow a) is tilted from the molecular alignment direction (direction of arrow b) of the liquid crystal molecules 8 by 45 degrees, therefore, the compositional light of the linear polarized light P_a in the molecular alignment direction, i. e., P_b, can pass through the liquid crystal layer 8 **[Note from the Translator-3]**. As a result, the linear

polarized light P_b, which passed through the liquid crystal layer 8, enters into the polarizer 7 at the polarization condition which has the vibrational plane in the molecular alignment direction of the liquid crystal layer 8. This polarizer 7 only passes the light which has a vibrational plane forming a 45 degree angle (direction of arrow d) from the molecular alignment direction of the liquid crystal layer 8 (the direction of arrow b). Therefore, among the linear polarized light P_b which has passed through the liquid crystal layer 8, the compositional light P_d in the molecular alignment direction can pass through the polarizer 7.

On the other hand, when the same voltage is applied to these two comb-tooth electrodes 10 and 10 and, at the same time, an alternating current is applied between the counter electrode 4 and these two comb-tooth electrodes 10 and 10, an electric field perpendicular to the surfaces of the substrates 5 and 5 is generated, as shown in Figure 9. As a result, the liquid crystal molecules 8 align to the direction of the electric field, therefore, the molecular alignment is in the perpendicular direction from the surfaces of the substrates 5 and 5. In such the molecular alignment condition, the linear polarized light P_a which has passed through the polarizer 6 has little influence in its polarization condition when passing through the liquid crystal layer 2. Since the polarizers 6 and 7 are placed perpendicular to each other, the linear polarized light P_a is blocked by the polarizer 7.

As described above, in the said conventional liquid crystal element 1, the molecular alignment condition of the nematic liquid crystal is varied to the direction either perpendicular or horizontal to the substrates 5 and 5 in a forceful manner by switching the directions of the applied electric field through the input signal, which controls the light shielding condition and light transmitting condition. Therefore, this method offers a <u>higher response rate</u> than the TN liquid crystal mode by almost 100 times.

<u>[Problems solved by Invention]</u>

However, in the said conventional liquid crystal element 1, there are no electrodes formed in the spaces between the comb-tooth sections 9, 9.... arranged in stripes. Therefore, the application of the alternating current between the said counter electrode 4 and these two comb-tooth electrodes 10 and 10 did not lead to a perfectly perpendicular electric field. Consequently, the liquid crystal molecules 8 did not align at the complete perpendicular condition. Therefore, the light shielded condition is still influenced by the birefringence of the liquid crystal molecules, and the <u>leaked</u> light from the polarizer 7 has caused a problem of the reduced contrast ratio. In addition, for the <u>control</u> of the light shielding condition and the light transmission condition, the liquid crystal molecules 8 of the nematic liquid crystal are designed to align in two alignment conditions; the perpendicular alignment and the horizontal alignment. As a result, the liquid crystal molecules 8 are designed to rotate as much as 90 degrees. Consequently, the switching

characteristics are rather insufficient and the desired high speed drive has not been achieved.

Therefore, the present invention aims to solve the said disadvantages in the said conventional type liquid crystal element.

[Methods to Solve Problems]

In the present invention, the said problems are solved by a liquid crystal element which characteristically possesses the first pair of comb-tooth electrodes and the second pair of comb-tooth electrodes, both of which are constructed with two comb-tooth electrodes, each having a section of multiple comb-teeth which is aligned alternatively from each other, by being positioned through the liquid crystal layer, wherein the said first pair of the comb-tooth electrodes and the second pair of the comb-tooth electrodes are positioned so that their length directions intersect each other.

In the liquid crystal element with such the constitution, the electric field is applied to two comb-tooth electrodes in the first pair of the comb-tooth electrodes.

By doing so, the liquid crystal molecules within the liquid crystal layer can change their alignment direction along the said electric field direction (B direction). Therefore, among the light entering to the said liquid crystal layer, only the light vibrating to the molecular alignment direction of the said liquid crystal molecules (B direction) can pass through the said liquid crystal layer. Then, by shifting the switch the electric field is applied to between two comb-tooth electrodes in the second pair of the comb-tooth electrodes. By doing so, the liquid crystal molecules within the liquid crystal layer change their alignment direction along the electric field direction generated by the second pair of the comb-tooth electrodes (C direction). Therefore, among the light entering to the said liquid crystal layer, only the light vibrating to the molecular alignment direction of the said liquid crystal molecules (C direction) can pass through the said liquid crystal layer. As a result, the light vibrating to the B direction can not pass through the liquid crystal layer and be shielded. In the liquid crystal element of the present invention, the angle between the B and C directions may be set arbitrarily. Therefore, the appropriate design of the angle between the B and C directions can control the rotation of the liquid crystal molecules from the B direction to the C direction, or vise versa, orderly and at high speed. Consequently, the light leakage may be suppressed and the contrast ratio may be increased. In addition, a high speed switching drive becomes possible.

Below, the liquid crystal element of the present invention is interpreted by referencing figures. Figures 1 and 2 present an example of the liquid crystal element of the present invention. In these figures, the same constitutional components as the conventional type are provided with the same code for the simplification of the interpretation. In the liquid crystal element 11 of this

example, the largest difference from the said conventional liquid crystal element 1 is the employment of the second pair of the comb-tooth electrodes, in place of the counter electrode 4. In other words, the liquid crystal element 11 of this example employs the known first pair of the comb-tooth electrodes 3 and the second pair of the comb-tooth electrodes 12.

Both of these first pair of the comb-tooth electrodes 3 and the second pair of the comb-tooth electrodes 12 are constructed with two comb-tooth electrodes 10 and 10 having multiple comb-tooth sections 9, 9..... by arranging each of the comb-tooth sections 9, 9.... alternatively.

These first pair of the comb-tooth electrodes 3 and the second pair of the comb-tooth electrodes 12 are placed through the liquid crystal layer 2, and the said first pair of the comb-tooth electrodes 3 and the second pair of the comb-tooth electrodes 12 are placed so that the length directions of the said comb-tooth sections 9, 9.... intersect each other. In this case, the crossing angle is desirably designed to be 20 degrees to 70 degrees, more preferably in the range from 40 degrees to 45 degrees. Further the polarizers 6 and 7 are placed at the outside of the first pair of the comb-tooth electrodes 3 and the second pair of the comb-tooth electrodes 12, respectively, by being perpendicular to each other. This polarizer 6 is designed to pass only the light vibrating to the length direction of the comb-tooth sections 9, 9.... of the first pair of the comb-tooth electrodes 3. Next, the switching operation of the liquid crystal element 11 of the said constitution is described. As shown in Figures 1 and 2, the light that enters to the polarizer 6 of the liquid crystal element 11 is emitted from the polarizer 6 as the linear polarized light PA having the vibration plane in the A direction. In such the condition, the no voltage is applied to two comb-tooth electrodes 10 and 10 constructing the first pair of the comb-tooth electrodes 3, and at the same time the desired alternating signal is applied to two comb-tooth electrodes 10 and 10 constructing the second pair of the comb-tooth electrodes 12. Then, the liquid crystal molecules 8 within the liquid crystal layer 2 change their alignment direction along the C direction, the direction of the electric field generated by the second pair of the comb-tooth electrodes (the direction cutting through the comb-tooth sections 9, 9... of the second pair of the comb-tooth electrodes 12). As a result, only the compositional light in the C direction can pass through the liquid crystal layer 2 among the linear polarized light PA having the vibrational plane in the A direction. By this procedure, the linear polarized light PA is optically rotated by the said liquid crystal layer 2 and emitted from the liquid crystal layer 2 as the linear polarized light PC having the vibration plane in the C direction. This linear polarized light PC enters the polarizer 7, among which only the compositional light in the D direction can pass the polarizer 7 and be emitted as the linear polarized light PD. This condition is the light transmitting condition, as indicated by the code S2 in Figure 3.

Then, the switch is shifted, and no voltage is applied to two comb-tooth electrodes 10 and 10 constructing the second pair of the comb-tooth electrodes 12, and at the same time the desired alternating signal is applied to two comb-tooth electrodes 10 and 10 constructing the first pair of the comb-tooth electrodes 3. Then, the liquid crystal molecules 8 within the liquid crystal layer 2 change their alignment direction along the B direction, the direction of the electric field generated by the first pair of the comb-tooth electrodes (the direction cutting through the comb-tooth sections 9, 9... of the first pair of the comb-tooth electrodes 3). As a result, only the compositional light in the B direction can pass through the liquid crystal layer 2 among the linear polarized light PA having the vibrational plane in the A direction. However, the A and B directions are perpendicular to each other, therefore, there is no compositional light in the B direction among the linear polarized light A. Consequently, the linear polarized light PA is shielded by the said liquid crystal layer 2 and no light is emitted from the polarizer 7. This condition is the light shielded condition, as indicated by the code S1 in Figure 3.

According to the liquid crystal element 11 of this example, the angle formed by the direction of the first pair of the comb-tooth electrodes 3 (the B direction) and the direction of the second pair of the comb-tooth electrodes 12 (the C direction) may be designed arbitrarily (for example, a smaller angle of at most 50 degrees). Therefore, the rotation of the liquid crystal molecules 8 from the B direction to the C direction, or vise versa, may be controlled orderly and at high speed. As a result, light leakage can be suppressed, and the contrast ratio may be increased. In addition, a high speed light switching becomes possible.

[Examples]

The liquid crystal element 11 shown in Figures 1 and 2 was prepared by the method described below. At first, surfaces of two sheets of glass substrates were uniformly covered with chromium in order to form a chromium layer with a desired film thickness.

Then by photolithography, the comb-tooth electrode pair pattern consisting of a pair of comb-tooth like electrode patterns was formed. In other words, concerning to this comb-tooth electrode pair pattern, the pattern shape and sizes for one comb-tooth like electrode pattern were: 2μm in the comb-tooth section line width, 8 μm in the line width pitch, and 6 comb-tooth sections in total. In addition, two comb-tooth like electrode patterns with the said constitution were arranged so that each comb-tooth section consisting of 6 teeth was alternatively placed with a line width pitch of 2 μm. By this method, the comb-tooth electrode pairs 3 and 12 which form one pixel were formed. Further, on these comb-tooth electrode pairs 3 and 12, polyimide resin was coated on by a spinner with a film thickness of 1,000 angstroms, in order to obtain a polyimide resin layer.

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Then, this polyimide resin layer was placed in the thermostat vessel at 250 °C for 1 hour in order to cure by the thermal treatment.

Further then, the polyimide resin layer on the first comb-tooth electrode pair 3 was processed by rubbing in the direction of the electric field applied to the first comb-tooth electrode pair 3 (the direction cutting through the comb-tooth sections 9, 9....). In addition, the polyimide resin layer on the second comb-tooth electrode pair 12 was processed by rubbing in the direction with the certain angle from the direction of the electric field applied to the second comb-tooth electrode pair 12 (the direction cutting through the comb-tooth sections 9, 9....). Here, the certain angle means that the rubbing directions of the polyimide resin layers placed on the comb-tooth electrode pairs 3 and 12 match when the first pair of the comb-tooth electrodes 3 and the second pair of the comb-tooth electrodes 12 are arranged so that the length directions of the said comb-tooth sections 9, 9.... of these intersect each other.

Then UV curing resin was coated at the thickness of about 4 μm on the surroundings of the surface having the polyimide resin layer on one substrate 5. Then two substrates 5 and 5 were adhered by setting their comb-tooth electrode pairs 3 and 12 facing to each other and by setting the angle formed between these comb-tooth electrode pairs 3 and 12 to 45 degrees. By using a UV irradiator, UV light was irradiated and the said UV curing resin was cured in order to form a cell. A nematic liquid crystal "9160" (trade name, manufactured by Chisso) was injected into this cell and the injection opening was sealed with UV curing resin.

This was once heated to the isotropic condition, and then gradually cooled in order to obtain a uniform molecular alignment along the rubbing direction. Then, the polarizers 6 and 7 were placed at both sides of this cell in such the manner that they were perpendicular to each other and that the polarizer 6 passed only the light vibrating to the length direction of the comb-tooth sections 9, 9.... of the first comb-tooth electrode pair 3.

Next, the liquid crystal element 11 manufactured by the said method was driven by switching under the following conditions.

The voltage between two comb-tooth electrodes 10 and 10 constructing the first comb-tooth electrode pair 3 was set to 0 V, and a rectangular alternating wave (a pulse width of 100 μsec and the maximum voltage of 20 V) was applied to two comb-tooth electrodes 10 and 10 constructing the second comb-tooth electrode pair 12, as shown in Figure 4. This resulted in a light transmitting condition as shown by the code S2 in Figure 3. Then by shifting the switch, the voltage between two comb-tooth electrodes 10 and 10 constructing the second comb-tooth electrode pair 12 was set to 0 V, and a rectangular alternating wave (a pulse width of 100 μsec and the maximum voltage of 20 V) was applied to two

comb-tooth electrodes 10 and 10 constructing the first comb-tooth electrode pair 3, as shown in Figure 5. This resulted in a light shielding condition as shown by the code S1 in Figure 3. In the said switching operation, the response time was about 300 μsec, and the contrast ratio was at least 30. As a result, the performance applicable to the high speed printer was obtained. In this example, the rubbing direction of the polyimide resin film was set to be perpendicular to the direction of the vibration plane of the linear polarized light PA entering to the liquid crystal layer 2, therefore, the light leakage was further suppressed. This increased the contrast ratio even further.

Further in the said example, the polarizer 6 was placed so that the vibrating plane of the linear polarized light which has passed through the polarizer 6 was along the length direction of the comb-tooth sections 9, 9.... of the first comb-tooth electrode pair 3. However, the application is not limited to this example, and the polarizer 6 may be placed so that it is along the length direction of the comb-tooth sections 9, 9.... of the second comb-tooth electrode pair 12. In such the case, the light shielding condition and the light transmitting condition are reversed from the conditions in the said example. In addition, the polarizer 7 may be placed so that the vibrating plane of the linear polarized light which was emitted from the polarizer 7 is along the length direction of the comb-tooth sections 9, 9.... of the first comb-tooth electrode pair 3 or of the second comb-tooth electrode pair 12. In addition, the rubbing direction of the polyimide resin layer is not limited to the said example, and the said rubbing direction may be the direction between the B and C directions as long as the rubbing directions of the polyimide resin layers holding the liquid crystal layer 2 are the same.

[Effects of Invention]

As interpreted above, the liquid crystal element of the present invention can result in a uniform electric field by placing the first pair of comb-tooth electrodes and the second pair of comb-tooth electrodes, both of which are constructed with two comb-tooth electrodes, each having a section of multiple comb-teeth which is aligned alternatively from each other, through the liquid crystal layer.

Therefore, the forced electric field can even better control the molecular alignment of the liquid crystal molecules. In addition, the said first pair of the comb-tooth electrodes and the second pair of the comb-tooth electrodes are positioned so that their length directions intersect each other with a certain angle. By appropriate design of this angle, the rotation or the reverse rotation of the liquid crystal molecules may be controlled orderly at high speed. By this procedure, the light leakage is further suppressed, and the contrast ratio is increased. In addition, a high speed switching becomes possible.

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4. Simple Interpretation of Figures

Figures 1 and 2 are disassembled perspective views for a liquid crystal element example of the present invention. Figure 1 presents the operation condition for the liquid crystal element to transmit light, and Figure 2 presents the operation condition for the liquid crystal element to shield light. Figure 3 presents the brightness of the transmitted light at the light transmitting condition and at the light shielding condition of this liquid crystal element. Figures 4 and 5 present the applied rectangular pulses for the switching drive of this liquid crystal element. Figures 6 through 9 indicate the conventional liquid crystal element. Figure 6 is the disassembled perspective view, and Figures 7 through 9 are cross-sectional diagrams of the component.

1, 11 - liquid crystal element, 2 - liquid crystal layer,
3 - first pair of comb-tooth electrodes, 9 - comb-tooth section
10 - comb-tooth electrode,
12 - second pair of comb-tooth electrodes

Notes from the Translator

1. Page 175, Inventor name (Page 1, Inventor name)
Both the first and the last name of the inventor are unusual, however, there is little chance for other ordinal ways to read these names.

2. Page 175, Claim 1 (Page 1, Claim 1) and throughout the text
In general, the fax copy of this patent is extremely poor in quality and there are many illegible sections. Those Kanji totally illegible are shown by xx, with the number of x corresponding to the number of illegible characters, and those reasonably estimated but not known exactly are shown by underlines.

3. Page 176, upper right, lines 10-18 (Page 2, the last paragraph to Page 3, 1st paragraph)
In this paragraph, the liquid crystal layer is coded as 8, which should be the liquid crystal 2.

(Figures are omitted in the draft copy).